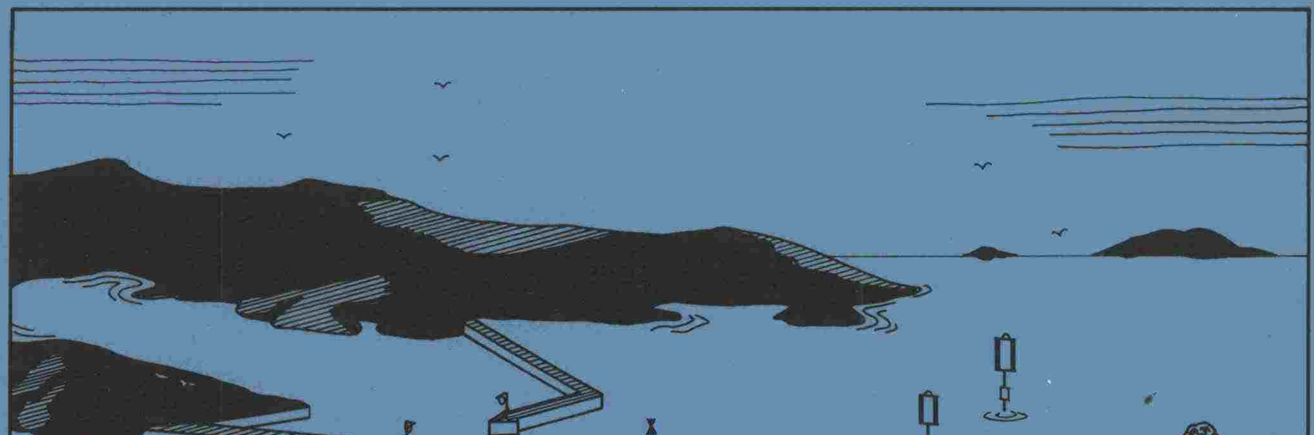
AIDS TO NAVIGATION IN FINLAND

PAAVO SARKKINEN



NATIONAL BOARD OF NAVIGATION
1984

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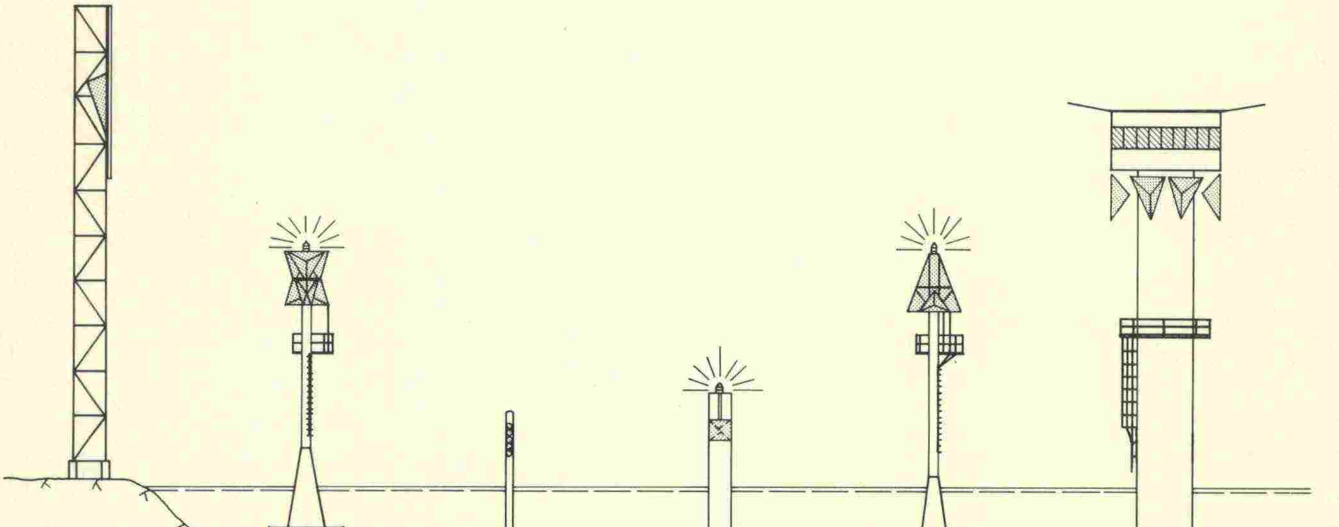
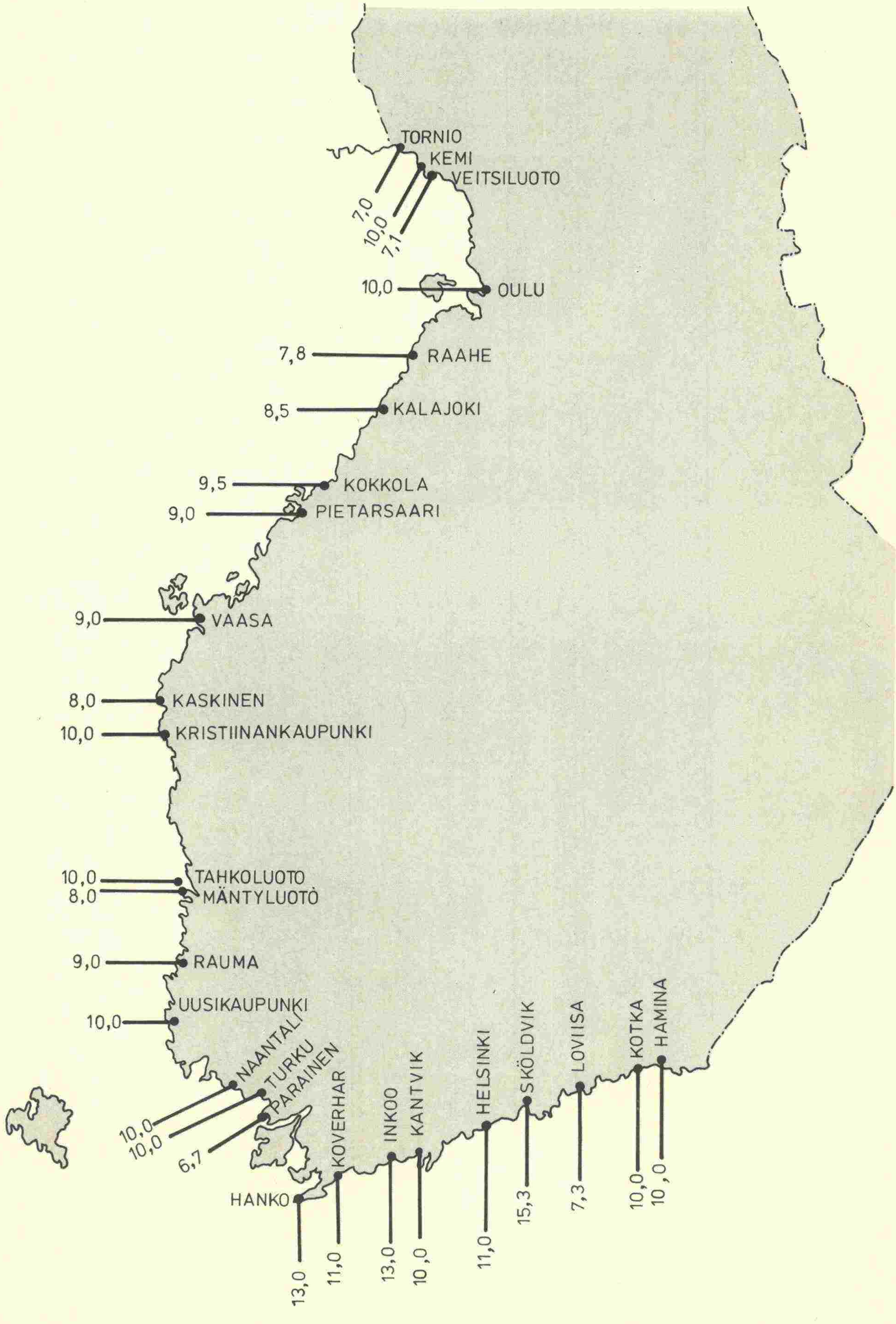


HELSINKI 1984

The most important ports and their allowed maximum draught



1. Waterways and navigation

Maritime channels of a total length of 6700 km and inland waterways measuring in all 6100 km are marked on the Finnish nautical charts and supplied with aids to navigation numbering about 21400.

There are on the coast 47 ports maintaining traffic on foreign countries. Of these, the most important 22 are open throughout the year. The National Board of Navigation has at its disposal 10 ice-breakers, which have guaranteed access to all winter ports since 1971. In addition, 10 ports in the lake system of Saimaa have sea-connection through the Saimaa canal during 8 ½ months of the year.

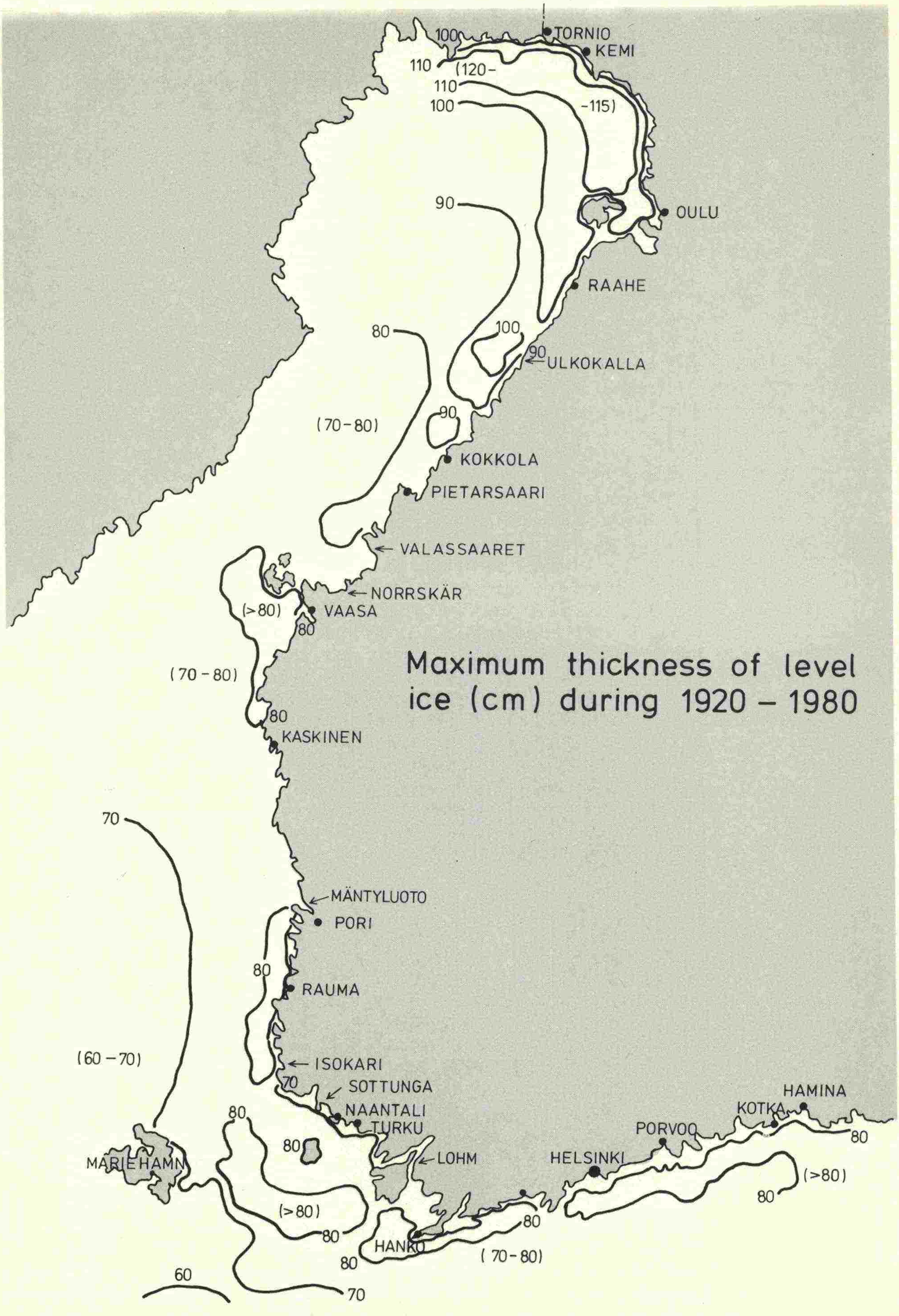
The total annual freight in foreign maritime trade amounts to nearly 50 million ton, 32 million of which are import, 18 million export. Within the country some 8 million ton yearly are conveyed on water. About 86 % of the cargo traffic utilizes those 19 ports which have an allowed draught of at least 9.0 m. The deepest channels lead to the oil refinery at Sköldvik (15.3 m) and the coal harbour at Inkoo (13.0 m).

The annual expenditure on the construction of maritime channels amounts to some 40 million FIM, ca 60 % of which are spent on dredging, ca 40 % on the construction of aids to navigation. Running and maintenance costs for the maritime channels amount to about 50 million FIM annually.

2. Environmental factors

The hard winters and the very low coast profile necessitate certain special features in the planning of appropriate aids to navigation for Finnish channels. The channels to all Finnish ports are frozen part of the year. The ice situation is most difficult in the Kemi channel, where the winter season lasts for half a year and the level ice in hard winters may be 110 cm thick. The problems are least in the Hanko channel, where the duration of the winter season is only a few months and the thickness of level ice in extremely cold winters is some 80 cm. The total length of the coast is 1100 km, and the archipelago outside it consists of over 20000 islands and rocky islets. In the archipelago ice may get anchored to islands and rocks and thus remain stationary, but outside this zone drift ice at times forms ridges even 30 m high.

The coast being low, the channels to the ports are long. The Finnish soil is very hard. In many places the rock shows up, in others it is covered by a thin moraine layer and boulders. Sedimentary earth deposits, which are easily dredged, are rare. As a rule, channels are made as narrow as possible owing to the high costs of dredging, and this necessitates a high-class system of marking. Consequently, a large number of aids to navigation have to be constructed and they must function perfectly even under difficult conditions.



Maximum thickness of level ice (cm) during 1920 – 1980

3. Navigation on the open sea

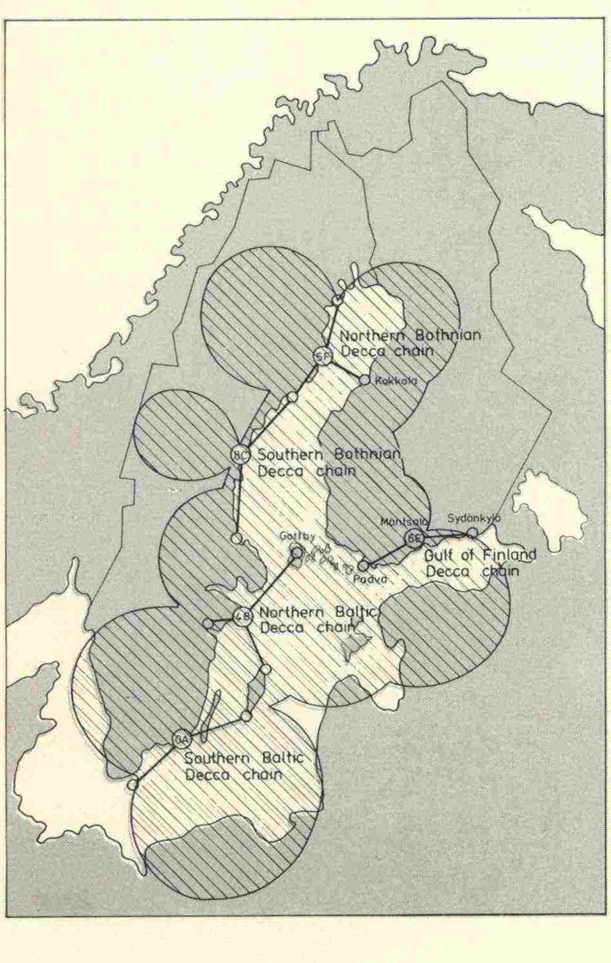
The determination of position on the open sea is based on Decca chains, radio beacons and lighthouses.

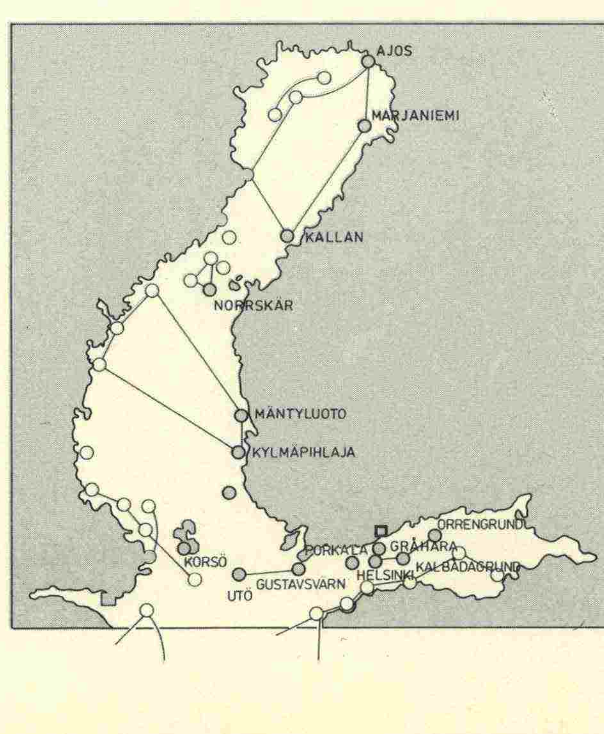
Finland has five Decca stations, two of which cooperate with Swedish chains. In the Baltic the determination of position by Decca is sufficiently accurate for navigation on the open sea. The range of error varies from 20 to 2000 m depending on the position and local conditions. Of the coastal areas the most inexact are the nothern part of the archipelago between the mainland and the Åland islands, the southern part of the Gulf of Bothnia and the area west of Hanko.

Navigational safety on the open sea is furthermore enhanced by the use of radio beacons, of which there are 15 in Finland. The network of radio stations in the Baltic is sufficiently dense.

The marine lighthouses located at the entrances to the archipelago channels have a range of over 20 km. Hence, vessels near the coast may utilize them for the determination of position also, either visually or by the aid of radar.

During the next few years it seems likely that the determination of position by the aid of satellites will be adopted. The new system will function parallel with the Decca system and the radio beacons. In no case will it supersede the present practice until, perhaps, the 1990s. A system of navigation based on satellites will, moreover, require some kind of reserve system.





4. Navigation in channels

The determination of position in archipelago channels and entrances to ports is dependent on fixed and buoyant aids, placed either at the edge of the channel or further off. The fixed aids at the edges are randmarks, the floating ones are buoys and spars. Aids indicating the direction of travel, placed off the channel, are leading marks and leading lights. Other fixed points for the determination of position are beacons, radar marks and daymarks.

In daylight and good visibility the marks are identified by their shape and colour. In good visibility at night illuminated marks are identified by the colour and rhythm of the light or by reflectors illuminated by searchlight. At other times the aids are localized by radar. Beacons, randmarks, radar marks, buoys and leading marks as well as spar buoys furnished with radar reflectors are all visible on the radar display. Particularly important aids may be strengthened by racon installation.

Number of aids to navigation

Type of aid	Maritime channels pcs	Lake channels pcs	Total pcs
Spar buoys	5 476	7 070	12 546
Buoys	442	8	450
Leading marks			
-with lights	1 258	544	1 802
-without lights	1 482	1 635	3 117
Randmarks	85	-	85
Radar marks	105	-	105
Lighthouses	46	-	46
Radar beacons	51	-	51
Day marks	670	1 707	2 377
Beacons	647	177	824
Total	10 262	11 141	21 403

5. Principles of channel marking

Two different categories of aids to navigation to be used in channels may be theoretically distinguished. Primary aids must function even under the worst possible conditions, while the main purpose of secondary aids is to facilitate and simplify navigation. The chain of primary aids must be dense enough to guarantee safe navigation in the channel, but when marking is planned it is presumed, however, that the nautical equipment on board is high-class. The primary aids being indispensable, they must be constructed regardless of the price. On the other hand, investments in secondary aids may be subject to consideration.

Classified by the quality of aids to navigation, there are four categories of channels in Finland:

1. Channels trafficable under all circumstances throughout the year, ice-breaker assistance being available in the winter season. This category comprises the winter channels along the coast, which are protected by the archipelago, and the channels to the winter ports. These channels are of great importance to maritime commerce.

   In areas with drift ice the system of primary aids in channels of this category comprises lighthouses, randmarks, radar marks and leading marks visible on the radar display. In areas with level ice there are, in addition, buoys fitted with efficient radar reflectors (plastic buoys with a diameter exceeding 100 cm). For secondary marking leading marks, beacons, buoys, spars and daymarks are used.

2. Channels used independently of visibility in the winter also, though ice-breaker assistance is not available. This category comprises all channels shallower than 7.0 m which do not belong to categories 3 and 4 and, in addition, deeper channels of no importance to maritime commerce.

   In areas with drift ice the system of primary aids in channels of this category encompasses all aids mentioned for category 1 and, in addition, ice buoys and in areas with level ice plastic spar buoys with a diameter exceeding 20 cm.

3. Channels to be used in the ice-free season independently of visibility. Examples of this category are some floating channels and the main boating routes.

   Primary marking in this category includes all aids visible on the radar display in the ice-free season and, in addition to those listed in group 2, buoys with radar reflectors and plastic and wooden spars.

4. Channels to be used only during the ice-free season and only in good visibility. To this category belong the majority of floating channels and boating routes.

   For the primary marking of these channels all existing aids to navigation may be used.

The above classification has led to considerable changes especially in the marking of channels of importance to maritime commerce. The following changes are noteworthy:

- Numerous fixed randmarks and radar marks are today required in areas where drift ice may occur.
- Adequately dimensioned, effective radar reflectors have to be installed in appropriate places.
- Leading marks are as far as possible made visible in radar.
- The importance of lighthouses and beacons has decreased and it is possible to dispense with strong light sources, in particular. The construction of sector lights is avoided.
- Fog horns are no longer needed.
- Buoys and spars that do not remain stationary are to be avoided. On the other hand, ice buoys of a new type and spar buoys remaining stationary also in ice are becoming increasingly important, as the marking of the edges of channels is being stressed.

6. Spar buoys

The Finnish channels are equipped with a total of some 12500 spar buoys, ca 7000 of which are laid out in inland waterways. About two-thirds of the spar buoys belong to the lateral system, one-third to the cardinal system.

Previously all spar buoys were constructed of wood. The present number of wooden spars is 5000, or 40 % of all. The float used in them is polystyren, and they are held in place by an anchorstone weighing 100 - 400 kg. All spar buoys are fitted with light reflectors, a proportion of the maritime spars also with topmarks. These are made of plastic and manufactured by Fiskars Oy at Tammisaari.

The wooden spars have to be installed afresh every spring. Only about half can be repaired, the remainder are destroyed during the winter. It has been a problem that wooden spar buoys do not remain stationary owing to their construction and weak mooring. They are damaged or displaced by log-rafts and ice. Today wooden spars are used in less important channels and in channels where plastic spars get broken by the movement of the ice.

Plastic spar buoys have in Finland been subject to development and tests for nearly ten years. Initially they were used in floating channels in the lake systems, but as they turned out a success, they have been put to use to an increasing degree in the maritime channels also. In connection with the marking reform in 1981 - 1982, a large number of new plastic spar buoys were laid out, and in 1983 the plastic spars in use totalled 7500, which makes 60 % of all spar buoys.

The plastic spars are made of plastic piping with a diameter of 40-500 mm. Mostly the diameter is 160 mm or 225 mm. The distinctive colouring does not wear off since the pigment is contained in the plastic. A spar consists of pipes of different colour, the ends of which are joined by welding, i.e. the ends of the pipes are heated and pressed together. The pipes are filled with foamy plastic to prevent the buoy from sinking if it is damaged. Plastic spars may be fitted with radar reflectors. In Finland all spars with a minimum diameter of 225 mm and a proportion of those with 160 mm diameter are fitted with radar reflectors. Retroreflecting strips are placed in grooves on the surface of the plastic pipes so that they may resist the wear from log-rafts and ice.

Plastic buoys are aids designed for long-term use. Their mean service period in Finnish conditions is estimated at ten years. Plastic buoys other than those used in boating channels are anchored by 1.0 - 3.0 ton weights. Most commonly 1.5 ton is used for spars 160 - 225 mm in diameter.

In case a log-raft or a driving ice-floe collides with a spar, the latter is pressed under the raft or floe, but it is not damaged. The capacity of the plastic spar buoys to endure the winter conditions is due not only to their effective mooring, it also depends on the fact that the adhesion between plastic and ice is only about 20 % that between wood or steel and ice.

Since the usual spars of uniform thickness have to be laid out in relatively deep water, a special kind of spars have been constructed for shallower channels. The underwater part of these spar buoys is made of thicker piping.

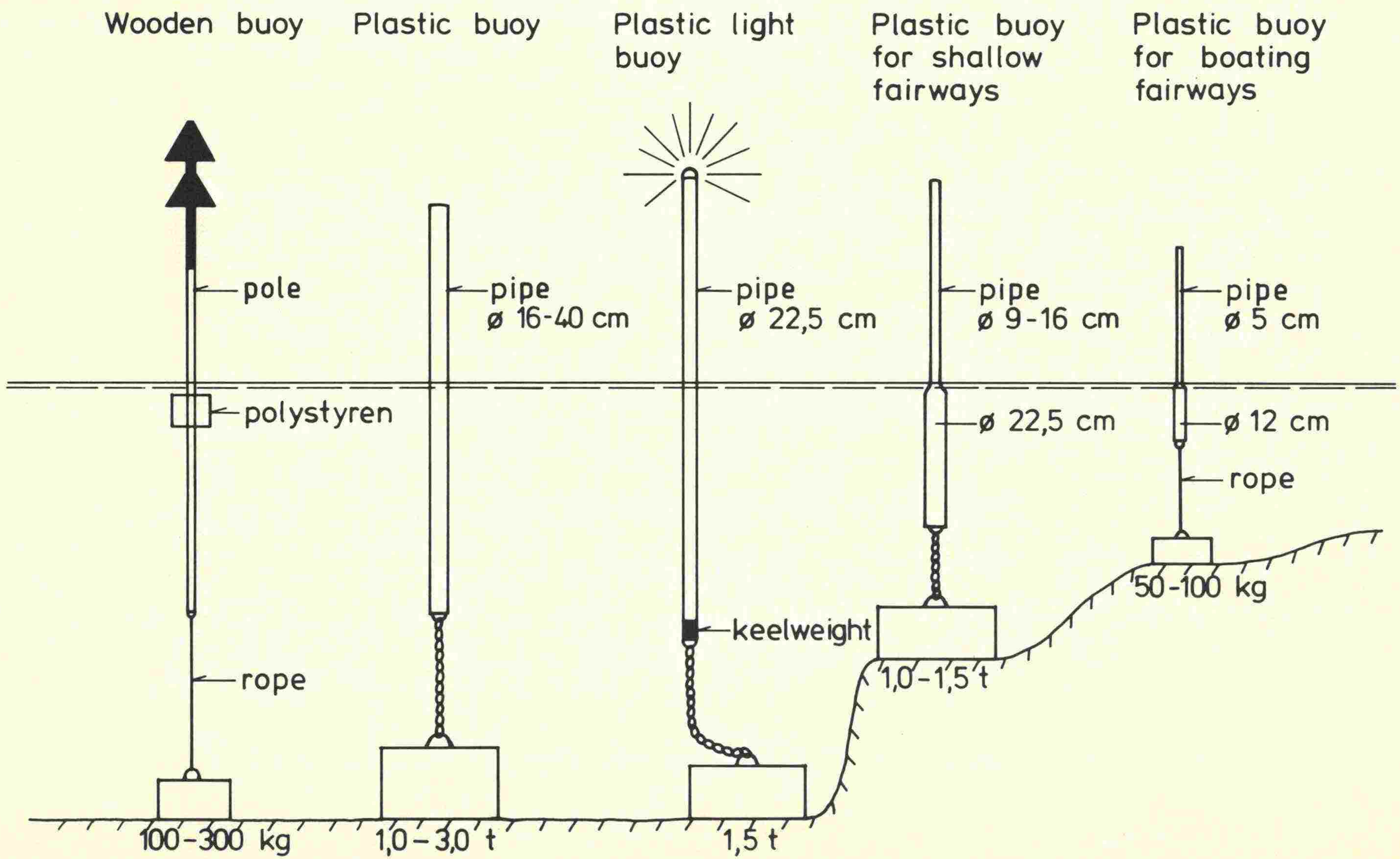
The spar buoys may, in addition, be fitted with lanterns. Batteries are then installed in the pipe, which must have a minimum diameter of 225 mm.

Finnish plastic spar buoys are mainly produced by the state-owned spar factory at Joensuu. The coloured plastic pipes are manufactured by Wiik & Höglund at Vaasa, who also produce spars for boating channels.

The colours of aids (spars, buoys and randmarks) located along the edges of channels, the shapes of topmarks and the various light characters are given in the international marking system (IALA:s rules for marking). On the other hand, no rules are given for shades, the dimensions of the coloured strips or the distictive features of light reflectors.

Field studies have been carried out in Finland in order to test the relative visibility of different colours. On the basis of the results, fairly light shades have been chosen. Light yellow (almost white), orange and light green are more readily seen than other shades in rain and dusk, in particular.

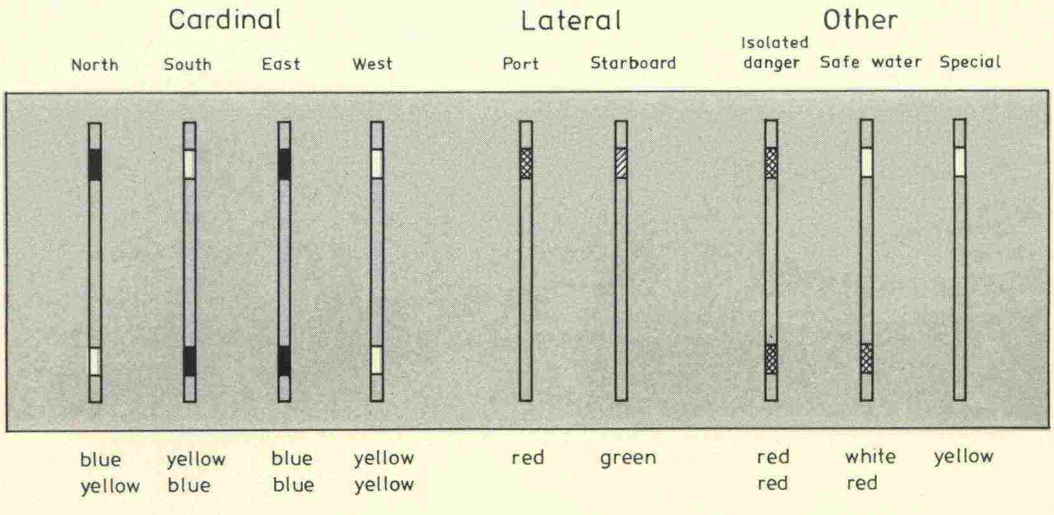
Spar buoys

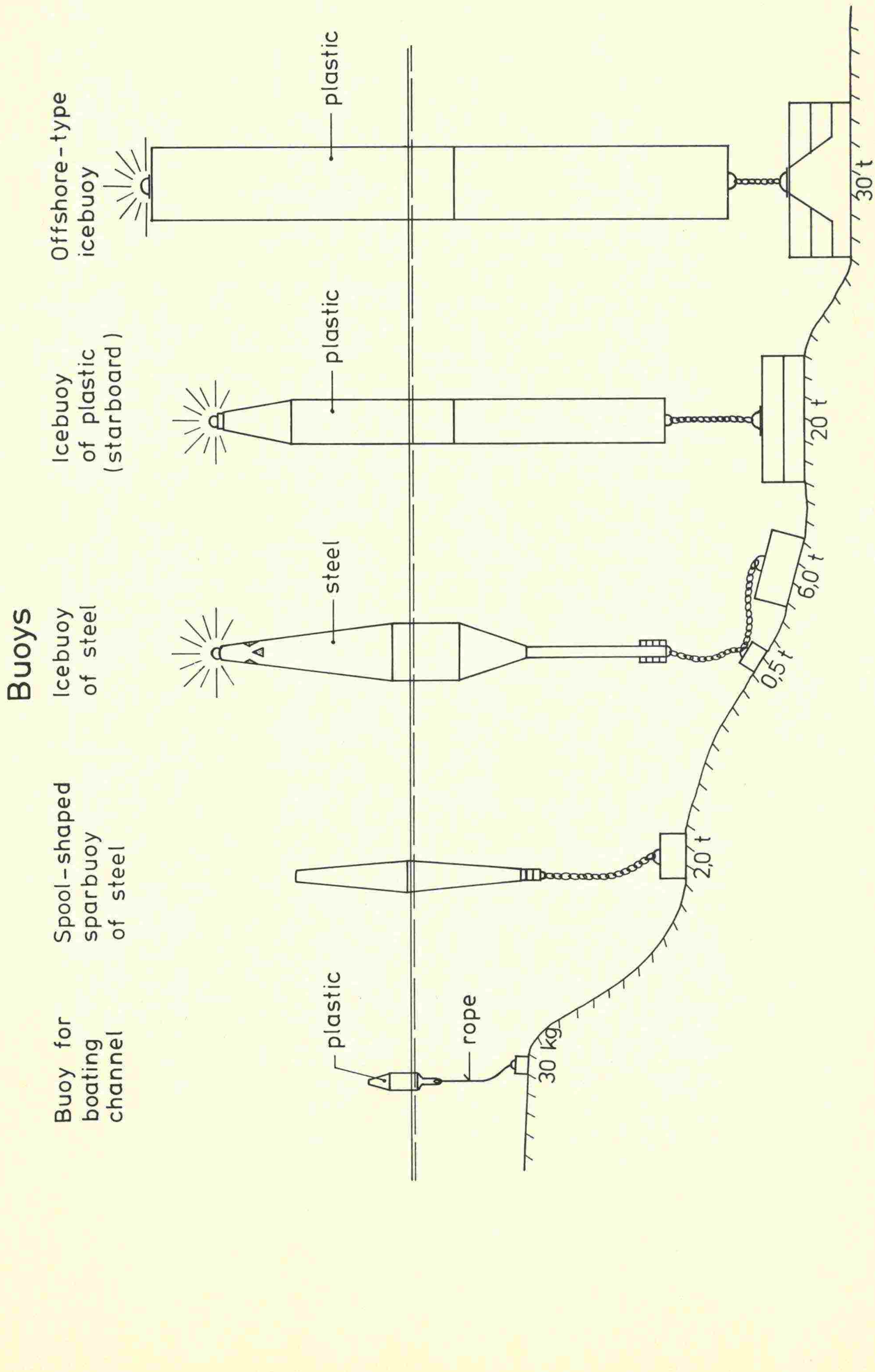

Wooden buoy
Plastic buoy
Plastic light buoy
Plastic buoy for shallow fairways
Plastic buoy for boating fairways
pole
polystyren
rope
100-300 kg
pipe ø 16-40 cm
1,0-3,0 t
pipe ø 22,5 cm
keelweight
1,5 t
pipe ø 9-16 cm
ø 22,5 cm
1,0-1,5 t
pipe ø 5 cm
ø 12 cm
rope
50-100 kg

In dimensioning the strips on cardinal marks, wave height and changes in the water-level have to be considered to guarantee that identification of the spars is possible under all circumstances. Identification of the topmarks of cardinal marks depends not only on their size but also on their distance from each other.

The criteria in developing the light reflecting system are that it must be logical and it must function in practice. On lateral marks one red or green retroreflecting strip suffices, but for identification of the four cardinal marks it has proved necessary to introduce a system with double strips, the colours of which are determined by the colours at the top and base of the spar. A blue retroreflecting strip corresponds to black, a yellow strip to yellow on the spar (though in Finland white is used because of its superior reflecting quality). In point of fact there is no other logical and adequate system. In order to be distinguishable, retroreflecting strips must be far enough from each other. For this reason the colours at the top and base of the spar are decisive in choosing the character of the reflex. On the other hand there is not room for more than two retroreflecting strips on a small spar.

Retroreflecting strips




Buoys
Buoy for boating channel
plastic
rope
30 kg
Spool-shaped sparbuoy of steel
2,0 t
Icebuoy of steel
steel
0,5 t
6,0 t
Icebuoy of plastic (starboard)
plastic
20 t
Offshore-type icebuoy
plastic
30 t

7. Buoys

In all, nearly 500 buoys are laid out in the Finnish channels. The majority are steel constructions, developed in the 1970s for use in winter conditions. By improvement of the lantern fittings, enforcement of the steel frame and strengthening of the mooring an icebuoy has been produced that resists the hard wear in archipelago channels.

Drawbacks of steel icebuoys are their poor visibility in radar and the reduction of the navigable channel width caused by their mooring system. The surface of a steel icebuoy is not large enough to hold a radar reflector capable of outdoing the disturbing echoes from the level ice. The width of the channel is increased if the buoy is anchored in the same way as spar buoys, and at the same time it is kept in exact position. Then, the buoy must be shaped like a pillar. In addition, its anchor system must be reinforced, since even small movements of the ice expose it to great strain.

In order to eliminate the problems described above, a type of buoy has been developed that functions like the plastic spar buoys. In this buoyant aid the relation between the height of the visible part (the part above the water-line) and the mean diameter is less than 5. In addition to the batteries required for the lantern, the plastic buoy can be fitted with a large and effective radar reflector, since the radio waves of the latter penetrate plastic. Owing to the weak adhesion between plastic and ice it is assumed that plastic buoys will prove more resistant than steel buoys to the wear of drift ice.

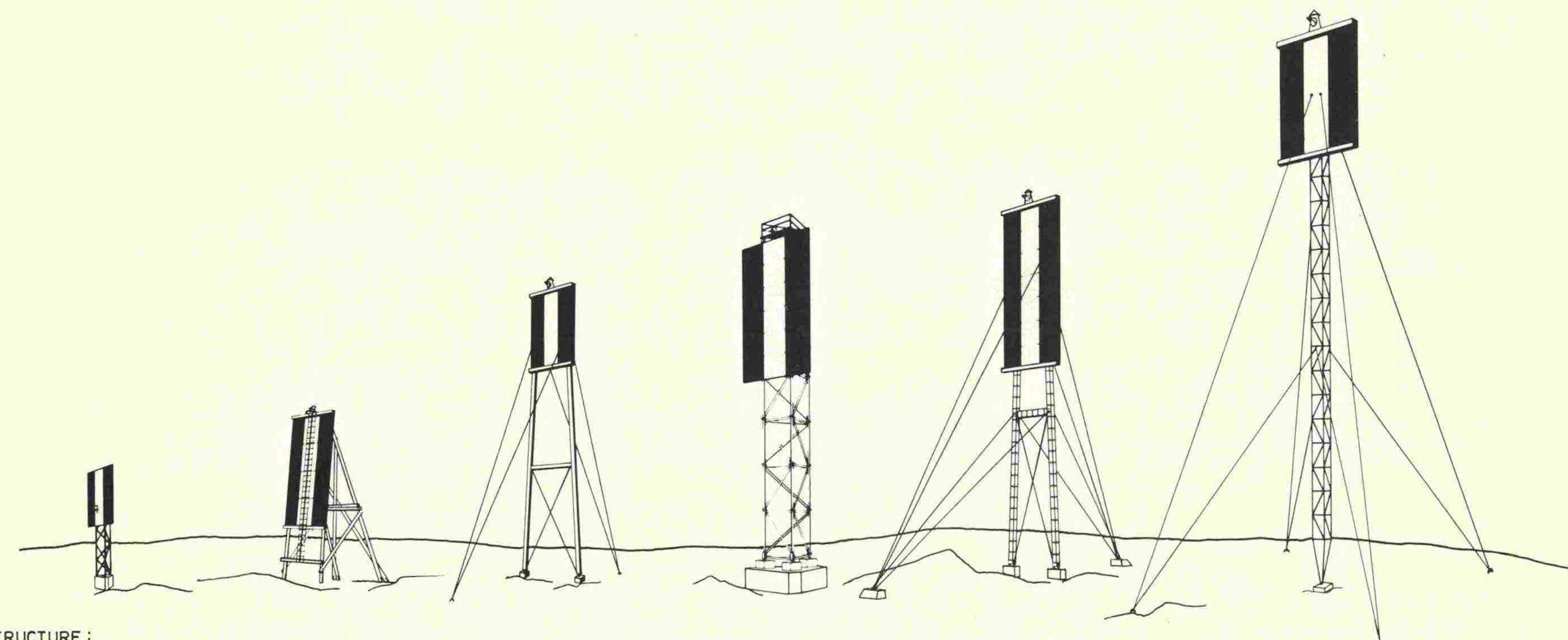
Sixty plastic buoys have already been laid out in the maritime channels. Their plastic pipe measures 100 cm in diameter and the total length of the buoy is 10 m. The height of the light source is 4,3 m.

Outside the archipelago buoys with a diameter of 160 cm will be tried out. The height of their light source is planned to be 600 cm.

The icebuoys are moored by concrete or rock anchors weighing 6 ton. The weight of the anchor is restricted by the capacity of the equipment employed in bringing them in position, or in other words by the hoisting capacity of the maintenance vessel. As the newer ones have a hoisting capacity of 10 ton, it is possible today to use heavier anchor weights. In buoys anchored in the same way as spar buoys, much heavier concrete anchors are used. These are made of several parts weighing 6 - 10 ton each.

The plastic buoys are manufactured by Wiik & Höglund in Vaasa. The lantern fittings for the icebuoys were developed by Ollituote, but they are today manufactured by Rencotuote at Porvoo.

Leading mark structures



STRUCTURE :	STEEL TRUSS UNIT	WOOD SCAFFOLD	GUYED A-FRAME OF WOOD	STEEL TRUSS MOUNTED ON SITE	GUYED A-FRAME OF STEEL	STEEL TRUSS GUYED IN FOUR DIRECTIONS
ECONOMIC HEIGHT OF TOWER :	< 12 m	< 15 m	10 – 20 m	10 – 35 m	15 – 35 m	30 m

8. Leading marks

The total number of leading marks in the Finnish channels is about 4900. Of these, 1800 are lighted. The leading marks are of different categories. In the boating channels 2 m high wood structures are used, with a panel measuring 1 m^2, while the leading marks in commercial channels may consist of a steel truss 40 m in height supporting a panel measuring nearly 100 m^2.

Considering the circumstances it is understandable that leading marks are used for the marking of Finnish channels. They are relatively cheap, stable and endurable, and as a rule it has been possible to locate them so as not to be exposed to the ice. A considerable drawback inherent in this marking system is that leading marks and lights are of little help in poor visibility, but leading marks located on flat islets or in radar shadow can be made visible in radar.

Although radar navigation presupposes that other aids are also constructed, the intention is to go on putting up leading marks in all channels where they can be advantageously located. Visibility is mostly good, and navigation in channels with the aid of leading marks is easy and uncomplicated. As a rule only that end of the leading line which demands the lowest construction costs can be marked, although marking both ends would greatly increase the ease of navigation, since the rear end is not readily seen from the bridge.

The leading marks and lights have to be dimensioned so as to be seen from a sufficient distance on the preceding line. The height of the look-out is different in different types of vessel. In small boats it may be 1 m, in merchant ships 30 m. The sensitivity of the line must be good in narrow channels. It is considered good if the distance between the front and rear marks is long. On sensitive lines small deviations from the route are readily observed. Since there are many variables in dimensioning tables and lights, the calculations have previously been laborious. Today they are easily and quickly made by computer.

The panels of the new marks consist of coloured, corrugated and transparent glass fibre sheets (Parawell sheets), manufactured by Parton Oy at Lohja. The most usual colours are red, yellow and white. The choice of colour depends on the background of the panel, whether rock, forest or sky.

Most of the costs for the line marking arise from the material for the trusses, because a considerable proportion of the panels have to be placed high. Special attention has therefore lately been directed to the development of cheap, serially produced types of truss. Low structures (under 15 - 20 m) are usually constructed of wood and high trusses (20 - 45 m) are made of steel. As regards construction costs, guyed structures are most advantageous, but it is not possible in all sites to use guys. Ice forced up onto the shore or lack of room are usual hindrances.

Electric leading lights are manufactured in Finland by Rencotuote Oy, while gas-lighted lights are manufactured by Aga Oy. Of the latter there are about 700. The gas-lighted leading lights are reliable, but the transportation of the heavy acetylene bottles is often a problem because of the rough ground on which the lights are situated. For this reason electric leading lights are becoming more frequent. When changes are made, preference is therefore given to using the ordinary electric mains. Batteries are employed as a source of energy in leading lights in the inland waterways, in particular, where the traffic is interrupted in the winter season from January to April. There are 650 leading lights run by batteries. In addition, wind generators and solar panels have been tested in Finland as sources of energy. Both have proved sufficiently reliable in Finnish conditions also, and they are advantageous in particular in places where the electric mains cannot be utilized and many leading lights can be supplied with energy from the same source.

On short lines, where the distance from the most remote point to the rearmost mark is less than 4 km, reflective panels may be employed instead of lights. On such lines the middle field of the panel is coated with a light-reflecting layer of high quality. So far only the Scotchlite High Intensity membrane delivered by Suomen 3 M Oy has been used. On the reflective leading line structures red Parawell sheets are used, because these are sufficiently well seen in daylight.

9. Randmarks

Randmarks are fixed aids located at the edge of the channel or some distance away. They are fitted with the characters indicated in the international system of marking. Since fixed marks located at sea are expensive owing to their exposure to ice, it is considered appropriate for economic reasons to allow the construction of randmarks within a range of 50 m from the theoretical edge. It is possible, as a rule, to find economically more advantageous sites for the construction of randmarks off the channel than at the edge. The construction costs are influenced by the depth of water and the type of sea bed. Not even in broad channels can randmarks be placed more than 50 m from the edge. In order to inform mariners about the exact position of the edge, the distance in meters between the centre of the randmark and the edge of the channel is given on the nautical charts.

Randmarks are typical aids to navigation in channels with drift ice. When made deeper, the channels become longer and extend far outside the archipelago. This necessitates the construction of more randmarks. During the last ten years nearly one hundred randmarks have been constructed in Finland.

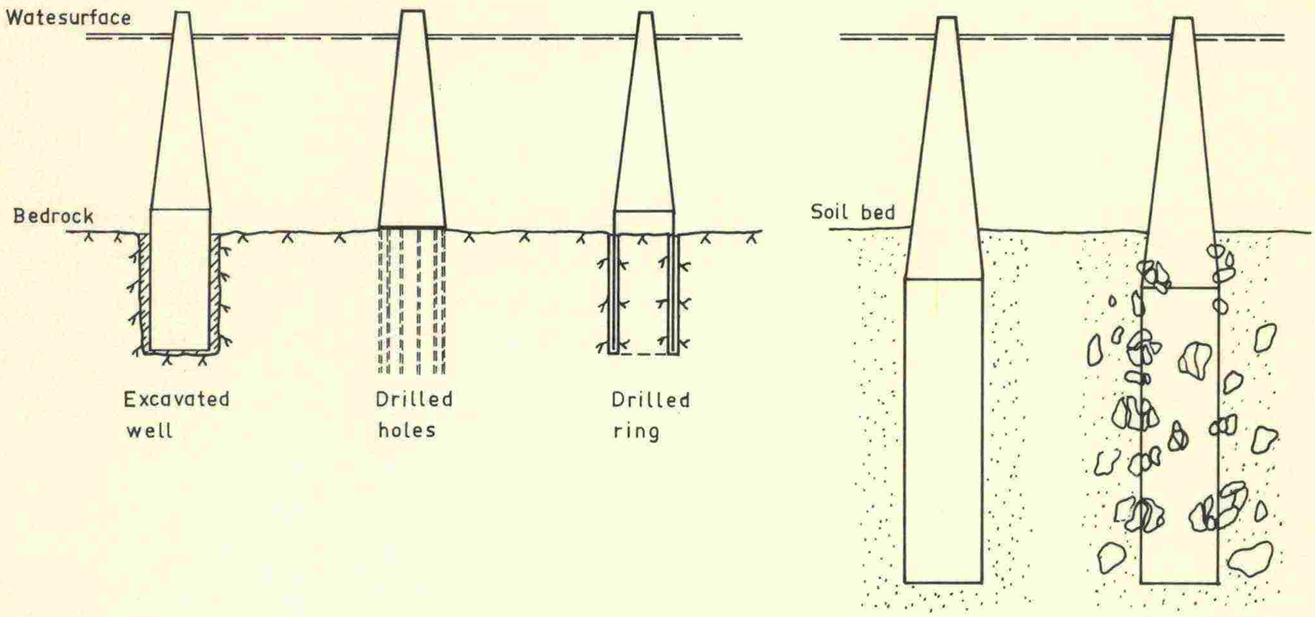
The most expensive part of a randmark is its foundation, in other words that part of the construction situated under the water-line. For this reason special interest has been directed to the development of new, cheap systems of foundation. Depending on the type of sea bed,

Foundationtypes for bottomfixed marks

STEEL FOUNDATIONS

Foundations on rock

Foundations on friction soil

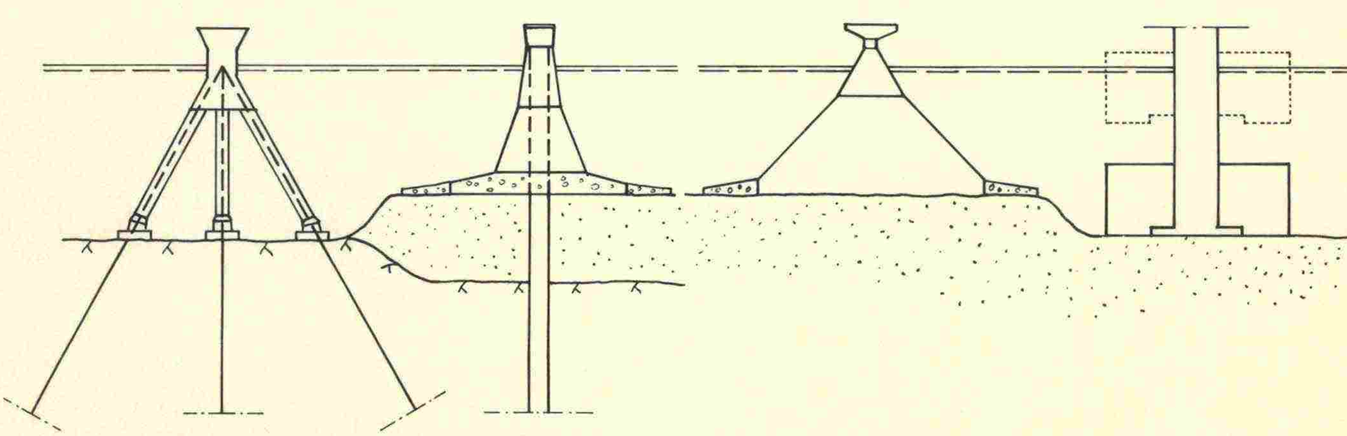


TYPE: Excavated well; Drilled holes; Drilled ring; Piled; Soil softened by blasting before pile-driving

CONCRETE FOUNDATIONS

Foundations on rock

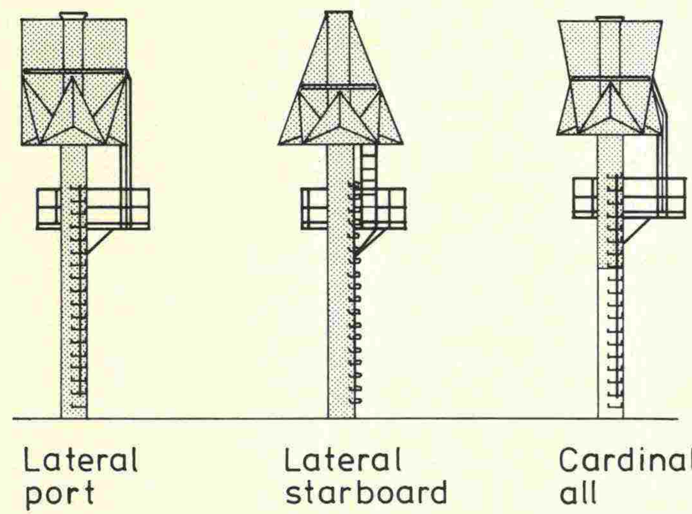
Foundations on friction soil

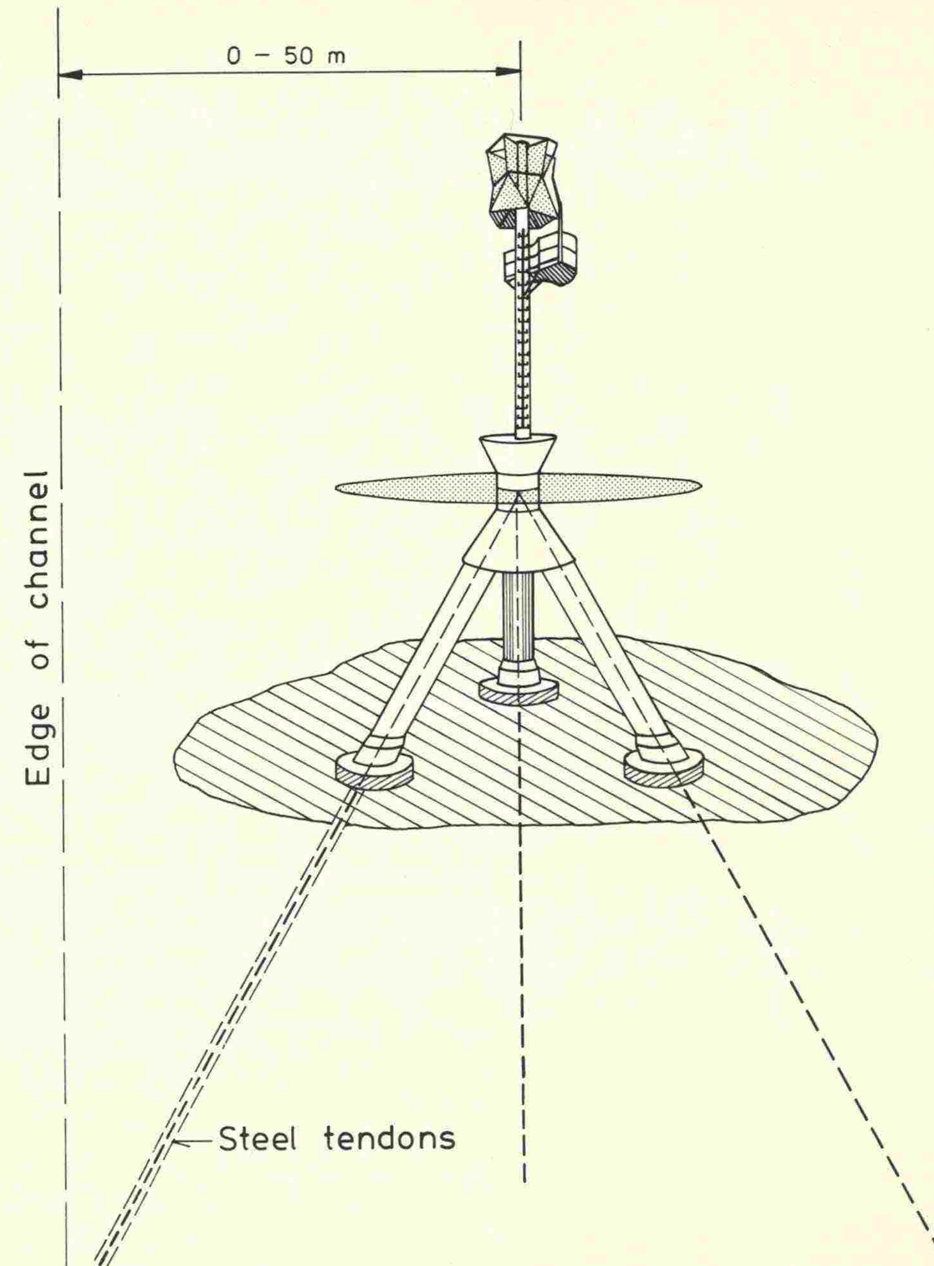


TYPE: Prestressed tripod; Prestressed cantilevered column on slab; Caisson or steelmould towed to site; Towable telescope-structure

Rand marks

Different types

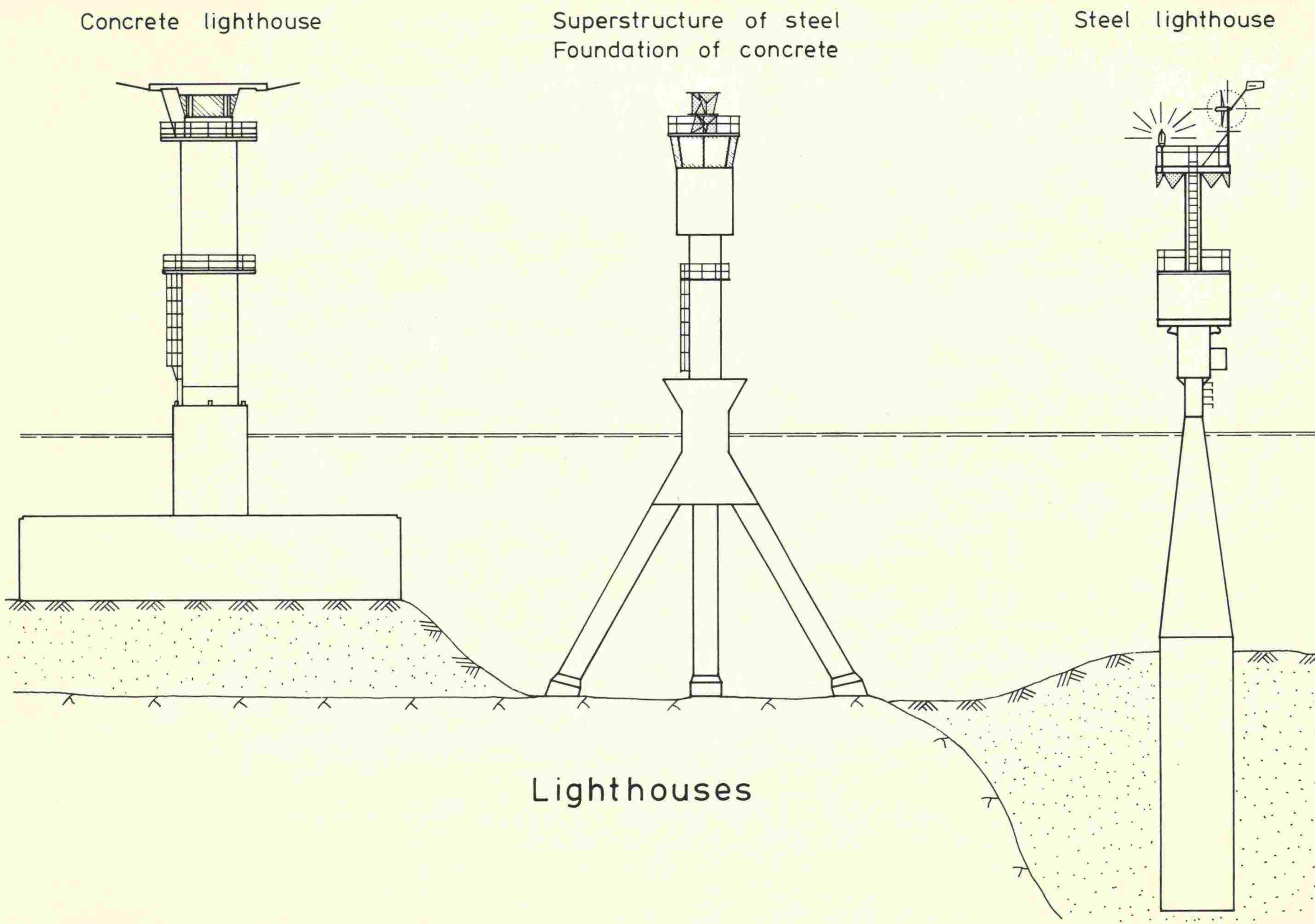




the foundation is made of steel pillars and huge steel piles, concrete frames fixed to the bedrock by steel tendons, or by in-situ laid concrete foundations cast into steel moulds and caissons. The foundations are designed so as to be resistant to the effect of ice. Another important point is that the hardship and duration of construction work at sea should be reduced as much as possible. Therefore, the foundations used today are not as heavy as previous structures. Modern steel foundations, for instance, are slender. Their diameter in water-level is only about 1,0 m. An advantage of this construction is the relatively slight pressure caused by the motion of level ice. On the other hand, the break-up of ice exposes the structure to heavy vibration. In dimensioning the superstructure and its equipment the vibrations at the foundation have to be considered.

The superstructure of randmarks, i.e. the part above water-level, is usually made of steel even if the foundation is concrete. Most commonly the height of the superstructure has been 12 m in commercial channels. The superstructure is equipped with the characters of the marking system. Thus, randmarks are either lateral or cardinal. Colour, light and reflective characters are used in all randmarks. In large randmarks, topmarks have not been considered necessary, but all lateral marks carry topmarks. On the other hand, it is considered important that randmarks constitute good radar targets, and they are therefore equipped with radar reflectors. The type used in Finnish channels is the 6-corner cluster comprising six corner reflectors, usually with an edge length of 100 cm. Provided that the target is not masked by any obstacle, this kind of radar target can be detected at a range of 10 km in all directions, even if radar visibility is restricted by rain or broken-up level ice. In lateral marks, radar reflectors may be mounted between the plates constituting the topmark. As for the cardinal marks, problems are encountered in designing conspicuous topmarks without restricting the effectivity of the radar reflectors or the safe passage required for service of the lighting equipment.

The lighting equipment applied to the top of a randmark must be resistant to strong vibration. At the top of a randmark acceleration may reach a level of 20 g ($200\ m/s^2$). The lighting equipment developed for randmarks is suspended in a shock absorber made of steel wire. Rencotuote Oy manufactures the equipment in two sizes. The lamp has an effect of 2-10 W, and with white light the intensity of the equipment is 40-500 cd, which gives a range of 7-15 km. The lighting equipment is generally supplied by batteries mounted below the radar reflector. This site has been chosen with a view to exposing the batteries to the least possible vibration. At the height where the batteries are placed, acceleration at the frame of the mark does not exceed 5-10 g.



Lighthouses

10. Radar marks

A fixed aid to navigation mainly intended to serve as a radar target and not belonging to the category of randmarks is called a radar mark. These are located at a distance of 50-5000 meters from the edge of the channel.

Radar marks are more readily constructed than randmarks because there is scope for variation in their location. It is often practicable to locate radar marks in sites with shallow water or on flat rocks in the outer archipelago. Radar marks constructed at sea have theoretically the same kind of foundation as randmarks.

The superstructures of radar marks and randmarks differ principally in that the characters of the marking system are not employed in the case of the former. As it is important that radar marks also function as visual signals, white and orange have been chosen for their colouration, since these colours stand out well in a marine environment.

The size and height of radar reflectors are determined by their location. The corner length of a good reflector is 100-150 cm and the most common height above water-level is 10-20 m.

Radar marks located near the channel are fitted with lighting equipment of the same kind as is used in randmarks, though the light characters deviate from those indicated in the marking system.

The radar marks are appropriate aids to navigation, and they are moreover advantageous from the viewpoint of construction and maintenance costs. For this reason many new radar marks will be constructed in Finland in the 1980s.

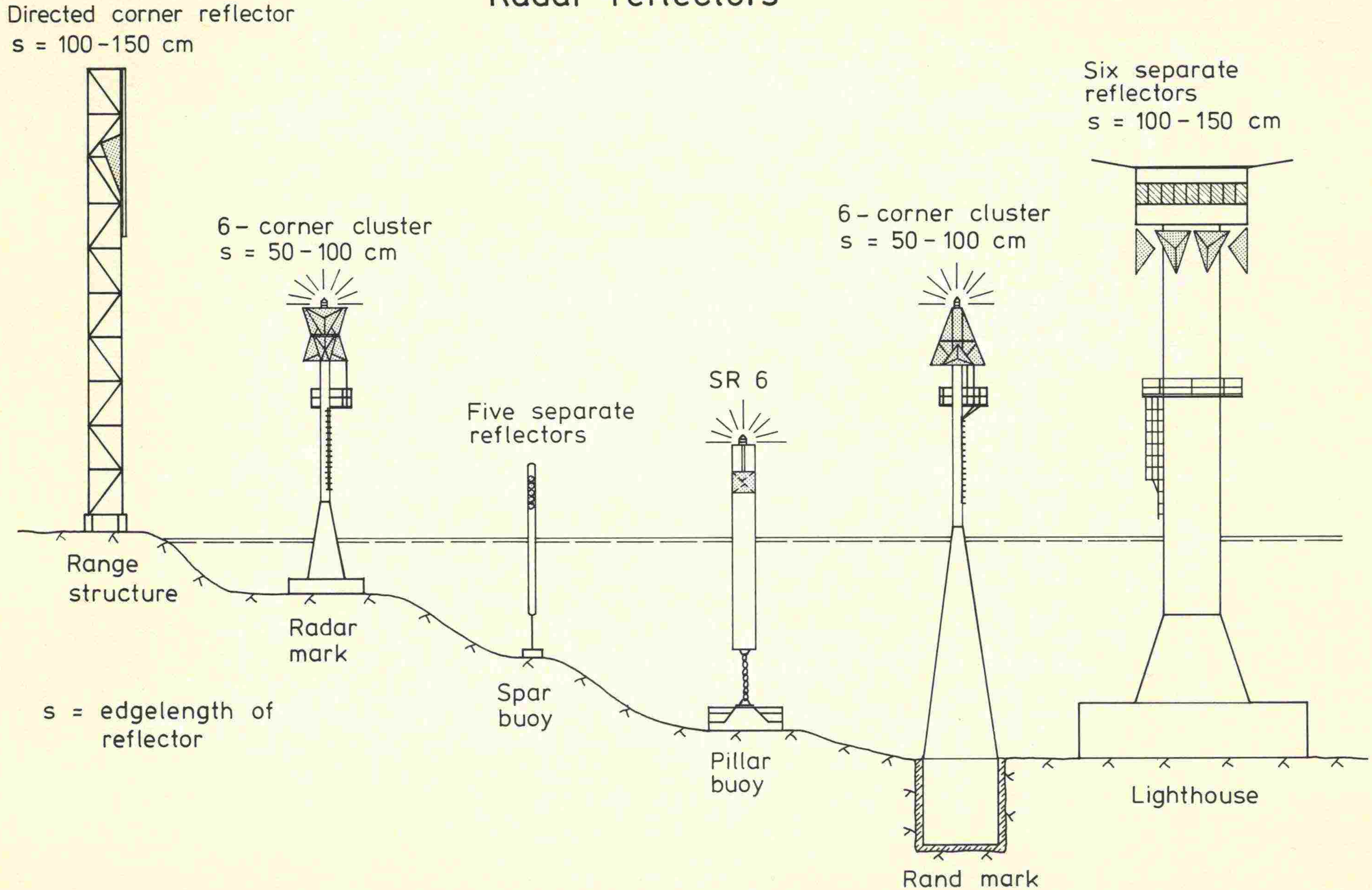
11. Lighthouses

Lighthouses in the open sea are usually located on a shoal or at a site where a channel starts. There are 46 lighthouses in Finland. The most important feature of a lighthouse has been its strong light effect. Considering the restricted visibility conditions sometimes prevailing some lighthouses are fitted with equipment for light signalling. Both these functions consume a great amount of energy and require careful service. In the open sea energy production and effective maintenance are costly.

The majority of Finnish lighthouses function with gas. All are automized, which means that no service personnel is needed. During the last few years many lighthouses have been furnished with helicopter platforms for the sake of securing their maintenance. A centralized, remote-controlled system for the supervision of lighthouses is being designed so as to make prompter repair possible.

The basic parts and prototypes of the equipment are under construction.

Radar reflectors



As a result of the development of the nautical equipment on board the ships, the importance of the lighthouses has decreased. The nautophones have been removed from a number of lighthouses and the remaining eight are likely to be removed within the next few years. In addition, the lighting equipment of the lighthouses will be simplified and their energy consumption will be cut down, which means that their light effect will be markedly diminished. An intensity of 1000- 10000 cd, which implies about 20 km visibility, is considered sufficient. However, as the light effect of the lighthouses is being reduced, their properties as radar targets must be improved.

The new lighthouses constructed in Finland are, in point of fact, effective radar marks with additional equipment, most commonly in the form of improved lighting equipment and radar beacon installation.

Improvement of the lighthouse constructions has run parallel with the development of other fixed aids to navigation at sea. Due to the low Finnish coastline and the fact that the significance of the lighthouses has changed, all lighthouses constructed during the last few decades have been located on the sea-bed.

The lighthouse foundations are theoretically similar to the foundations of randmarks. The design of the superstructure, on the other hand, is essentially different because the sensitive equipment of a lighthouse does not endure high acceleration. The highest permissible acceleration at the site where the equipment of a gas-operated lighthouse is installed is 0.5 g (5 m/s^2). This can be attained either by constructing sufficiently stable foundations or by isolating the superstructure from the vibration caused by the motion of ice. So far three vibration-isolated lighthouses have been constructed in Finland. The newest one is the Nukkujanmatala lighthouse in the Kemi channel, where the exposure to ice is heaviest.

The lighthouses vary in appearence. They are painted with colours that must be clearly recognized at long range. In the selection of colour it is a criterion that lighthouses and randmarks must differ from each other in this respect. Therefore, the colour characters of the marking system are not used for lighthouses.

The lighting equipment for the lighthouses has been delivered by Aga Oy.

12. Radar reflectors

The best passive reflector is the Luneberg lens, but the high manufacturing costs due to its special construction restrict its use.

Of the simple radar reflectors the corner cluster is the most effective. It is made up of three metal plates in the shape of right-angled equilateral triangles, all intersecting at right angles. The corner cluster reflects radar waves effectively at an angle of + 30 ° both vertically and horizontally. In order to yield as uniform echoes as possible in the horizontal plane, the corner cluster is composed of five or six corner reflectors. Trials have shown that more numerous corner reflectors do not produce a more uniform echo. On the contrary, the number of gaps increases due to interference.

The capacity of the radar reflector to reflect signals is determined by the radar cross-section (RCS) of the radar target. The maximum RCS of a corner cluster (K) can be calculated by the formula

$$K = V \times \frac{s^4}{\lambda^2}$$

where V = coefficient, λ = radar wave length (3 cm or 10 cm) and s = edgelength of the reflector. The effectivity of the radar reflector thus increases rapidly with an increase of its edgelength.

Another important factor influencing the performance of the radar reflector is its height above sea level. The reflector must be mounted sufficiently high to secure free contact with the radar antenna regardless of heavy sea conditions, islands and the curvature of the earth.

The principle in designing radar targets is that the radar reflector must have a larger RCS than the disturbing factors in its surroundings. The worst disturbance factors in Finnish conditions are broken-up level ice, heavy rain and fog. When the radar is adjusted so as to eliminate the disturbances, the target must remain on the radar display.

It is thus theoretically easy to design radar reflectors. Small aids to navigation such as spars and buoys are fitted with 5-6 corners, and these should be as large as can be accommodated and installed as high as possible. In randmarks, radar marks and lighthouses the edgelength of the radar reflector must not be less than 50 cm. On the other hand an edgelength exceeding 150 cm does not improve the performance. The height and alignment of corner clusters must be adapted to the local conditions.

Leading marks are fitted with a corner cluster adjusted to the line of navigation. It is usually mounted near the mast-head behind the frame of the leading mark. The panel of a leading mark can function as radar target if located at sea, on a flat rock or in radar shadow. In shadowed areas the reflector must be mounted so high that contact with the antenna is established above the obstacle causing shadow.

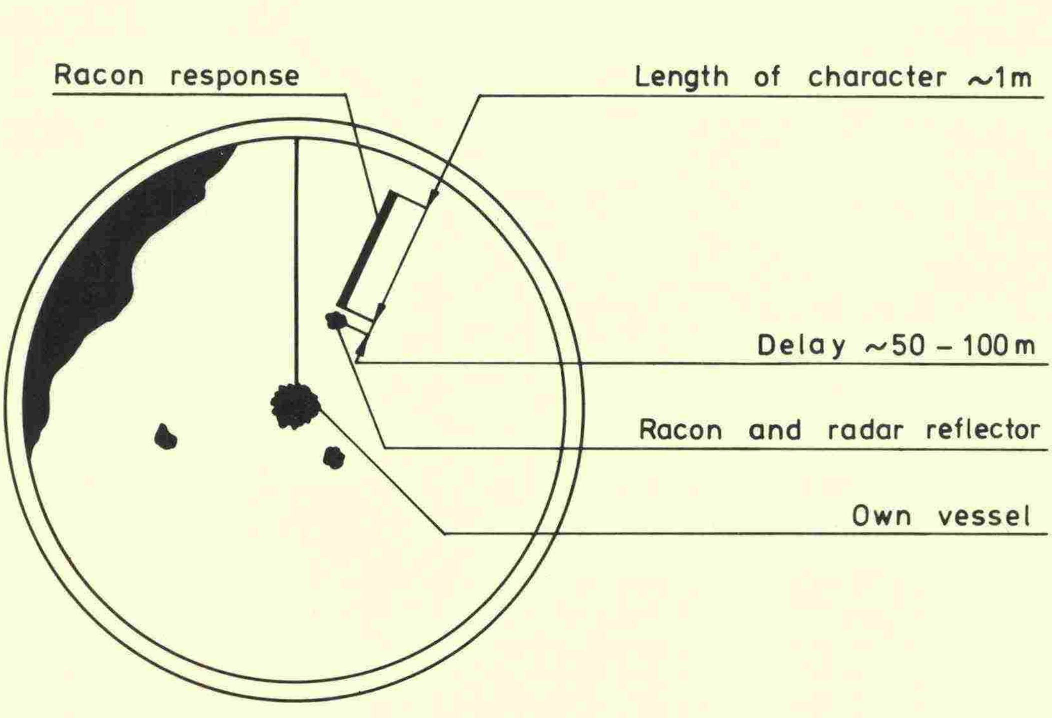
During the last few years the development of aids to navigation in Finland has focussed on a substantial improvement of the visibility of the aids in radar.

13. Radar beacons

The performance of a radar target can be improved by the application of a radar beacon. The identified target is used as a fixed point in the radar display. Radar beacons are used for the sake of eliminating the risk of mistakes in areas where there are several similar radar targets.

The National Board of Navigation has installed 51 radar beacons transmitting on varying frequencies, which appear on the radar display at 90 s intervals during 2 - 3 antenna scans. In addition, a radar beacon prototype has been designed in Finland, which transmits on a fixed frequency and is continuously presented on a marine radar display. The beacon receives the radar pulses of a ship within its sphere of influence and responds on the same frequency. This prototype has been constructed in duplicate by the engineering firm Juhana Ylinen. The beacons have functioned to satisfaction.

Radar beacons are being developed which allow the navigator to take in the beacon on his radar display according to his own choice.



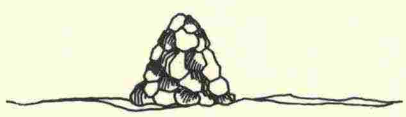
Racon response on a ship radar display

14. Daymarks

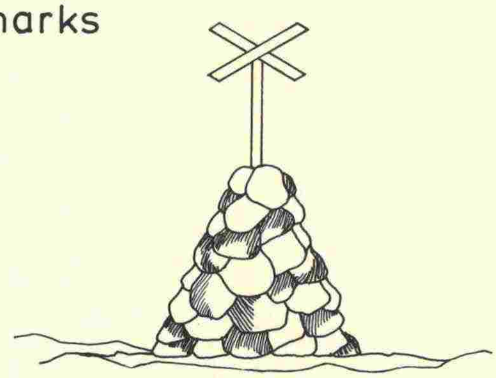
Cairns and other daymarks are no longer of any importance to the navigation of commercial vessels, but they may be useful aids to navigation in other types of traffic.

A new type of daymark has been developed for the Finnish boating and log-driving channels. Instead of the previous whitewashed cairns and log piles, daymarks resembling traffic marks will be constructed. They will consist of a supporting structure and a retroreflecting panel, visible by day and night. With a view to facilitating the determination of position, the daymarks will be fitted with distinctive characters to be marked on the nautical charts.

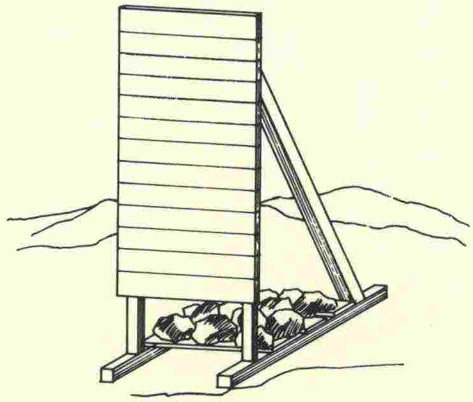
Day marks



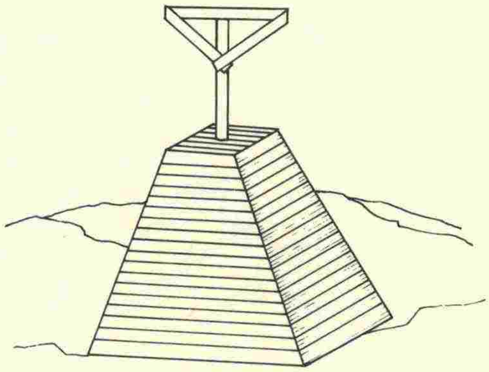
Whitewashed rockpile



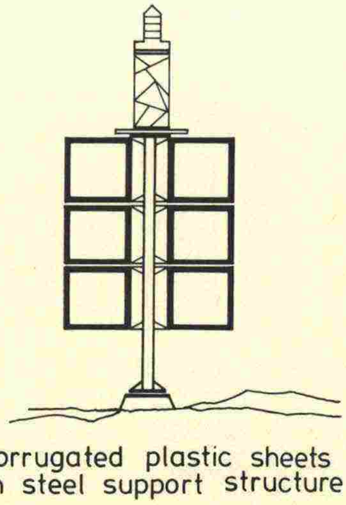
Rockpile with wooden identification sign



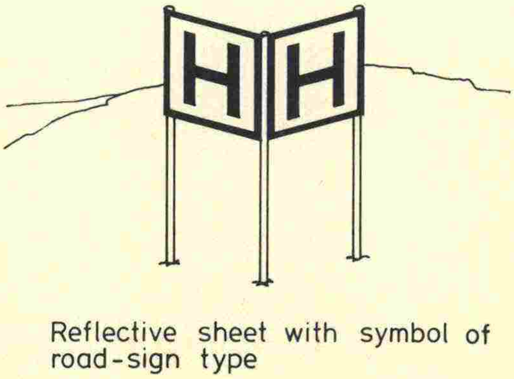
Wooden day mark painted white



White wood structure with identification sign



Corrugated plastic sheets on steel support structure



Reflective sheet with symbol of road-sign type

15. Construction program for channels

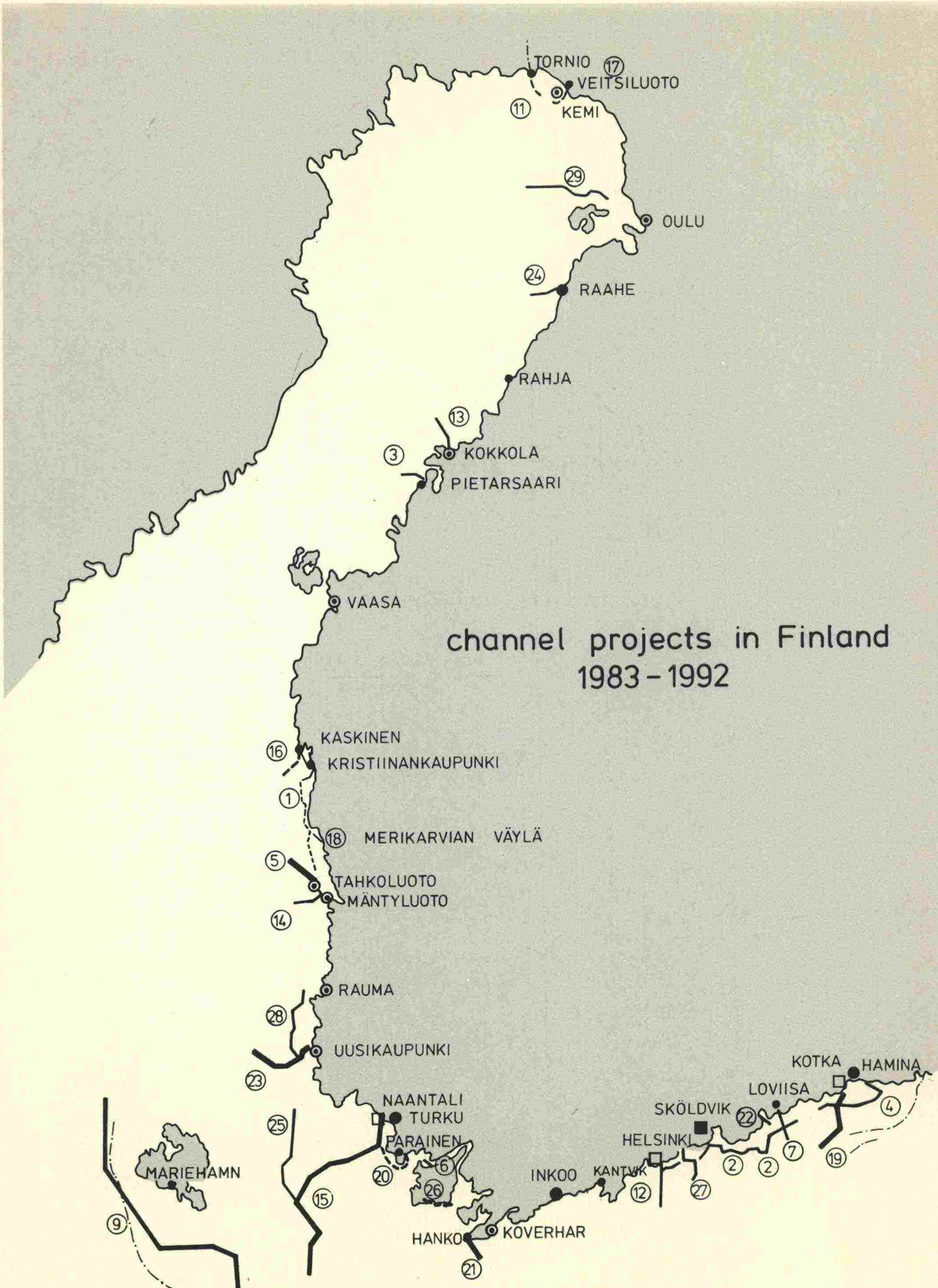
The National Board of Navigation has drawn up a program for the construction of marine channels for the period 1983 - 1992. Participants in the elaboration of the program have been, in addition to representatives of the National Board of Navigation, representatives of the Roads and Waterways Administration, the Ministry of Trade and Industry, the Finnish Harbour Association, the Association of Finnish Shipowners and the Central Industrial Association. The channel program is based on extensive investigations and thorough analyses performed in 1979 - 1982. Among these, mention may be made of

- an analysis of the need of channels to commercial coastal ports,
- the elaboration of a prognosis for the development of the shipbuilding industry,
- the elaboration of a prognosis for the development of marine transport,
- an investigation of potential sites for deep-water harbours,
- the elaboration of a prognosis for the development of aids to navigation and
- hydrographic surveys, soil analyses, channel designing and transport economic analyses relating to the channels proposed in the program.

These analyses have shown that in the case of many channels deepening will prove a profitable undertaking. An increase in depth to 11 - 15 meters is desirable in particular in channels used for the transport of coal, oil, grain, raw minerals, fertilizers and other bulk cargoes.

Deepening of the channel may be considered transport-economically advantageous in all cases mentioned in the program. Projects of this kind are only recommended in the channel program if the calculated real interest in the form of saved transport costs in 20 years amounts to over 6 % of the capital invested. In addition to the deepening of commercial channels, the program contains certain improvements considered necessary from the standpoint of navigational safety and certain projects relating to boating channels and service routes.

According to the price level in 1982, the construction program for marine channels involves a total cost of 600 million marks. Of this, investments in aids to navigation constitute 40 %, or 240 million marks. The intention is to realize the program at a steady pace during the 10-year period 1983 - 1992.


TORNIO
17
VEITSILUOTO
11
KEMI
29
OULU
24
RAAHE
RAHJA
13
3
KOKKOLA
PIETARSAARI
VAASA
channel projects in Finland
1983 - 1992
KASKINEN
16
KRISTIINANKAUPUNKI
1
18
MERIKARVIAN VÄYLÄ
5
TAHKOLUOTO
MÄNTYLUOTO
14
RAUMA
28
UUSIKAUPUNKI
23
NAANTALI
TURKU
25
PARAINEN
6
20
26
15
MARIEHAMN
9
8
HANKO
21
KOVERHAR
INKOO
KANTVIK
12
HELSINKI
27
2
2
SKÖLDVIK
22
LOVIISA
7
KOTKA
HAMINA
4
19

INVESTMENTS IN MARITIME CHANNELS 1983 - 1992

(Mmk)

PROJECT		Cost est.	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
UNSPECIFIED FINANCING												
a) Investigations and planning		-	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5
b) Minor channel and marking works		-	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
c) Damage repair of marking		-	2,5	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0
d) Untitled channel works		-	-	-	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0
PROGRAM FINANCING												
e) Service routes		10,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
f) Boating channels		10,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
g) Rand- and radarmarks		12,0	-	-	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
FINANCING OF PROJECTS IN PROGRESS												
1. Coastchannel Pori-Kaskinen		2,0	0,7	-	-	-	-	-	-	-	-	-
2. Winterchannel Helsinki eastward	9,0 m	8,4	2,0	1,0	-	-	-	-	-	-	-	-
3. Pietarsaari channel	9,0 m	14,5	6,0	3,0	-	-	-	-	-	-	-	-
4. Hamina channel	10,0 m	11,5	5,5	5,0	-	-	-	-	-	-	-	-
5. Tahkoluoto channel	15,3 m	41,2	16,0	18,5	5,7	-	-	-	-	-	-	-
FINANCING OF NEW PROJECTS												
6. Norrlångvik channel	4,2 m	3,8	3,8	-	-	-	-	-	-	-	-	-
7. Loviisa channel	8,0 m	7,5	3,9	3,6	-	-	-	-	-	-	-	-
8. Suomen Leijona lighthouse		5,6	2,6	3,0	-	-	-	-	-	-	-	-
9. Åland sea channel	15,3 m	15,0	5,4	6,6	3,0	-	-	-	-	-	-	-
10. Coastchannel for barges	4,6 m	6,0	1,1	1,2	1,2	1,2	1,3	-	-	-	-	-
11. Tornio channel	7,3 m	3,4	-	1,4	2,0	-	-	-	-	-	-	-
12. Sörnäinen channel	11,5 m	5,9	-	1,9	4,0	-	-	-	-	-	-	-
13. Kokkola channel	11,0 m	32,3	-	1,3	11,1	13,5	6,4	-	-	-	-	-
14. Mäntyluoto channel	9,0 m	12,0	-	-	6,0	6,0	-	-	-	-	-	-
15. Naantali channel	13,0 m	47,2	-	-	9,0	13,5	14,5	10,2	-	-	-	-
16. Kaskinen channel	8,0 m	3,0	-	-	-	3,0	-	-	-	-	-	-
17. Veitsiluoto channel	7,3 m	4,0	-	-	-	2,0	2,0	-	-	-	-	-
18. Merikarvia channel	4,0 m	4,0	-	-	-	1,8	2,2	-	-	-	-	-
19. Mussalo channel	15,3 m	17,0	-	-	-	-	6,0	8,0	3,0	-	-	-
20. Parainen channel	7,5 m	17,0	-	-	-	-	5,9	7,1	4,0	-	-	-
21. Hanko channel	12,0 m	4,0	-	-	-	-	1,2	2,8	-	-	-	-
22. Isnäs channel	5,5 m	3,0	-	-	-	-	-	3,0	-	-	-	-
23. Uusikaupunki channel	12,0 m	25,0	-	-	-	-	-	7,4	10,6	7,0	-	-
24. Raahe channel	9,5 m	69,0	-	-	-	-	-	-	15,4	21,0	18,0	14,6
25. Kihti-Isokari channel	10,0 m	18,0	-	-	-	-	-	-	4,5	6,0	6,5	1,0
26. Taalintehdas channel	8,0 m	2,0	-	-	-	-	-	-	-	2,0	-	-
27. Vuosaari channel	11,0 m	15,0	-	-	-	-	-	-	-	-	7,0	8,0
28. Isokari-Kajakulma-Rauma	10,0 m	8,2	-	-	-	-	-	-	-	-	3,5	4,7
29. Oulu channel	10,0 m	18,4	-	-	-	-	-	-	-	-	-	5,7
TOTAL			60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0